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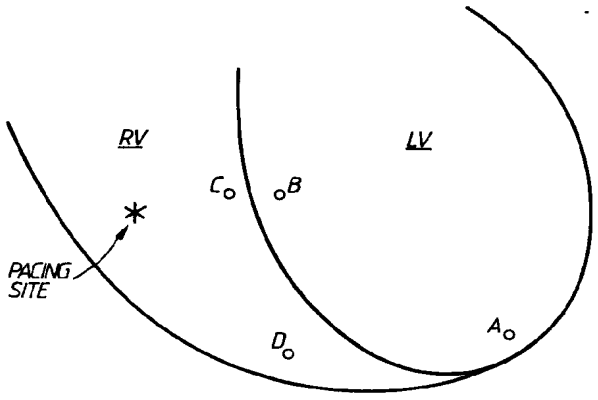
(54) Apparatus for recognition of ventricular tachycardia and ventricular fibrillation and for termination thereof.

(57) Apparatus for the automatic recognition of ventricular tachycardia and ventricular fibrillation compares pulse sequences which are obtained when sensing at at least one position on each ventricular epicardial surface of a heart. Changes in the sequence of activations and in the timing from pulsing at one sensor position to next pulsing at that position will indicate both ventricular tachycardia and ventricular fibrillation to enable a response to be made to restore to a pulse sequence representing the normal ventricular activity of the heart.



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APPARATUS FOR RECOGNITION OF VENTRICULAR TACHYCARDIA AND VENTRICULAR FIBRILLATION AND FOR TERMINATION THEREOF

This invention relates to apparatus for recognition of ventricular tachycardia and ventricular fibrillation from epicardial electrogram timings and for termination thereof.

Ventricular fibrillation is defined as a condition characterised by fibrillary electrical activity of the ventricular muscle, the electrical impulses traversing the ventricles so rapidly that coordinated contractions cannot occur. This must be distinguished from ventricular tachycardia which may be defined as a rapid (greater than 110 beats per min) cardiac rhythm originating in the ventricles. If sustained, it is usually synchronised in terms of overall ventricular contraction. Both should be differentiated from the normal situation of sinus rhythm where the heart's rhythm is controlled by depolarisation originating from the sinus node and which spread sequentially through the atria, the AV node, the His-Purkinje system and ventricular myocardium.

It is an object of the invention to provide apparatus for recognizing both ventricular tachycardia and ventricular fibrillation to be used with means for responding to both these conditions to restore normal heart rhythm.

According to the present invention, there is provided apparatus for the automatic recognition of ventricular tachycardia and ventricular fibrillation comprising:

at least two sensors for attachment of at least one sensor to each ventricular epicardial surface of a heart;

signal paths connecting the sensors to programmed means for detecting a pulse sequence representing the ventricular electrical activity of the heart and for comparing the pulse sequence detected with that

representing the electrical activity of the heart during normal ventricular rhythm of the heart; and

means for converting the detected pulse sequence into a form which will be useful for providing a corrective response to a pulse sequence representing the electrical activity of the heart during abnormal ventricular rhythm of the heart. The apparatus will generally be used in association with means for supplying to the heart stimuli to restore normal rhythm to the heart following detection of abnormal ventricular rhythm, in which case there may be no need for converting the detected pulse sequence into a readable form or other form, such as audible form, which makes a pulse sequence representing electrical activity of the heart during abnormal ventricular rhythm of the heart to be identified.

For a better understanding of the invention and to show how the same can be carried into effect, reference will now be made, by way of example only, to the accompanying drawings wherein:-

FIGURE 1 shows schematically an arrangement of four ventricular activation sites;

FIGURE 2 shows the electrograms obtained from the four sites during normal sinus rhythm;

FIGURES 3A, B and C show electrograms obtained under simulated ventricular tachycardia conditions;

FIGURE 4 shows the electrograms obtained at the four sites under conditions of ventricular fibrillation;

FIGURE 5 is a block diagram of a cardiac implant embodying this invention; and

FIGURE 6 is a flow diagram indicating the characteristic operation of the present invention.

The feasibility of automatic recognition of ventricular tachycardia and ventricular fibrillation has been examined in a number of patients undergoing coronary artery surgery. Bipolar epicardial electrograms from four discrete points on the surface of the heart have

been recorded during operation. The points are indicated on the ventricles of the heart. It has been observed that during normal rhythm, the points which are recorded are activated in a certain sequence which is at least consistent, although not always specific to that rhythm. Thus, referring to Figure 1 of the accompanying drawings, the locations of four discrete points numbered A, B, C and D on the left ventricle (LV) and right ventricle (RV) are shown, two of the points (A and D) being on the left ventricular and right ventricular apices and points B and C being at left ventricular and right ventricular paraseptal positions. A pacing site is located on the right ventricle adjacent the third point. During normal rhythm, activation took place in the sequence C, D, B, A in this particular case (see Figure 2). Furthermore, the timing from the first detected deflection to the last of the four was always the same during normal rhythm and in this example, because of normal rhythm, the timing is short, being of the order of 25 msec.

With abnormal rhythm, this timing will generally be increased and the sequence of activations changed.

This latter observation was established by simulation of an abnormal rhythm by pacing from the site on the right ventricle. It was observed that 8 out of a group of 10 patients paced at this particular site showed a change of sequence of activation compared with that seen during normal sinus rhythm. Recording of the sequences obtained showed that activations change from C, D, B, A to C, B, D, A. Another abnormality which was induced was that because a normal conducting system was not utilised, the spread of activity took longer across the heart so that the timing from the onset of depolarisation detected first at site C and finally at site 1 took 85 msecs as opposed to 25 msecs. Figures 3A, 3B and 3C indicate that this duration and sequence of activation is not affected by the rate of the abnormal

rhythm provided that its site of origin remains constant.

Maintaining the same set of sites, further experimentation to induce ventricular fibrillation yielded further results of interest. Ventricular fibrillation was induced by putting AC current onto a heart under cardiopulmonary by-pass (this is a means of obtaining cardiac arrest and often used during surgery). It was observed that during ventricular fibrillation, the electrical activity at all four sites was extremely rapid, and certainly more rapid than normally seen. However, there was no apparent fixed sequence of activation. The activity can therefore be described as asynchronous. Because of the asynchronous nature of activity, there can be no fixed duration of activity. This thus provides a means of using multi site testing to distinguish between ventricular tachycardia where there is likely to be an altered sequence of depolarisation compared with normal rhythm and an increased duration of activation over that occurring during normal sinus rhythm, and ventricular fibrillation when all this synchrony is lost and the electrical activity from different points in the heart becomes asynchronous.

Thus apparatus embodying this invention is programmed to respond to ventricular tachycardia or ventricular fibrillation when they are detected from an altered sequence and duration of ventricular activation as detected by impulses sensed from the epicardial sensing sites.

The present invention is of particular value in that ventricular fibrillation has so far been a very difficult rhythm to detect reliably automatically. Moreover, the energy required by an implantable device to treat ventricular fibrillation is likely to be higher than that required to treat ventricular tachycardia. Therefore by the use of this technique, lower energies can be selected for termination of ventricular tachycardia thereby prolonging battery life. There is

thus provided a reliable method for the first time of detecting ventricular fibrillation. The micro-computer utilised in the circuit for comparing activation sequence with that during sinus rhythm can then control a defibrillator which can be discharged when rhythm characteristic of ventricular fibrillation or ventricular tachycardia is detected. Appropriate software is provided for controlling the micro-computer.

Finally Figures 5 and 6 show practical embodiments of the invention and should be viewed in conjunction with each other. Thus an implant 1 which has sensors (not shown) at positions such as shown in Figure 1) will monitor heart rate beat at all times using a normal heart beat detector 2 having time base and backup pacing control 4 whose operation is directed by a microprocessor 5 having a memory 6. Should a high heart rate be detected, then a detector 3 which is normally operating in backup mode is switched on and simultaneous multi-channel sensing is carried out although Figure 1 shows that sensing at four sites is carried out, and this number is adequate in general, there is no reason why more or less than four sites may be used for testing, although the use of four sites has been found to be an optimum compromise between cost and sensitivity. The microcomputer 5 which is utilised with the detector and receives signals therefrom will check by means of memory 6 whether activation sequence and duration are compatible with sinus rhythm. If this is the case, then no action will be required. However, if the activation sequence and duration are not compatible with sinus rhythm, then provided that an activation sequence is synchronised indicating ventricular tachycardia, a response appropriate to treatment of ventricular tachycardia will be initiated, i.e. stimuli will be delivered by pulse generator 7. In certain cases, which depend on the type of tachycardia, however, ventricular tachycardia may be located by a relatively low energy shock for an

associated defibrillator 8. If the activation sequence is not synchronised, indicating that ventricular fibrillation is taking place then operation of the defibrillator 8 will take place.

Claims:

1. Apparatus for the automatic recognition of ventricular tachycardia and ventricular fibrillation characterized by:

at least two sensors (A,B,C,D) for attachment of at least one sensor to each ventricular epicardial surface of a heart;

signal paths connecting the sensors to programmed means (2,5,6) for detecting a pulse sequence representing the ventricular electrical activity of the heart and for comparing the pulse sequence detected with that representing the electrical activity of the heart during normal ventricular rhythm of the heart; and

means for converting the detected pulse sequence into a form which will be useful for providing a corrective response to a pulse sequence representing the electrical activity of the heart during abnormal ventricular rhythm of the heart.

2. Apparatus as claimed in Claim 1, which additionally comprises means (7,8) for supplying to the heart stimuli to restore normal rhythm thereto following identification of abnormal ventricular rhythm.

3. Apparatus as claimed in claim 2, wherein said heart stimuli supplying means (7,8) is adapted to supply less energetic heart stimuli in the event of ventricular tachycardia identification than in the event of ventricular fibrillation identification.

4. Apparatus as claimed in Claim 1, additionally comprising means for converting the detected pulse sequence into a readable form.

5. Apparatus as claimed in Claim 1, wherein for any predetermined arrangement of the sensors on the ventricular epicardial surfaces, the programmed means (5,6) is programmed to detect the time interval occupied by a predetermined number of pulses and the sequence of activations, both of which detected parameters are compared by the programmed means with the

same parameters when determined during normal rhythm of the heart.

6. Apparatus as claimed in Claim 5, wherein the programmed means (5,6) is programmed to detect asynchronous electrical activity at said heart surfaces.

7. Apparatus as claimed in Claim 1, which comprises four sensors (A,B,C,D) for application two to each of the two ventricles of the heart.

8. Apparatus as claimed in claim 7, wherein two of the sensors (A,D) are for application to the left ventricular and right ventricular apices and the other two sensors (B,C) are for application to the left ventricular and right ventricular paraseptal positions.

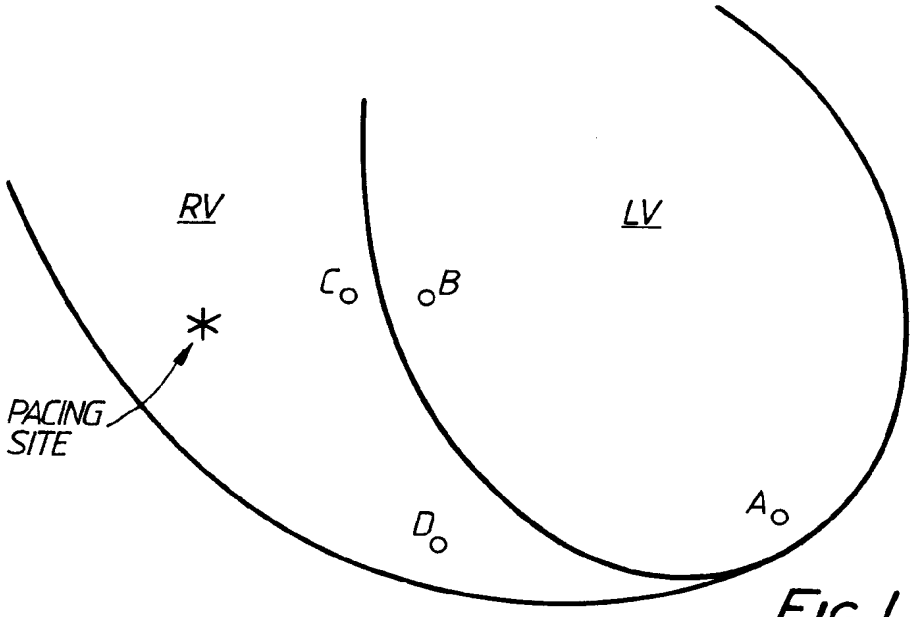

FIG. 1.

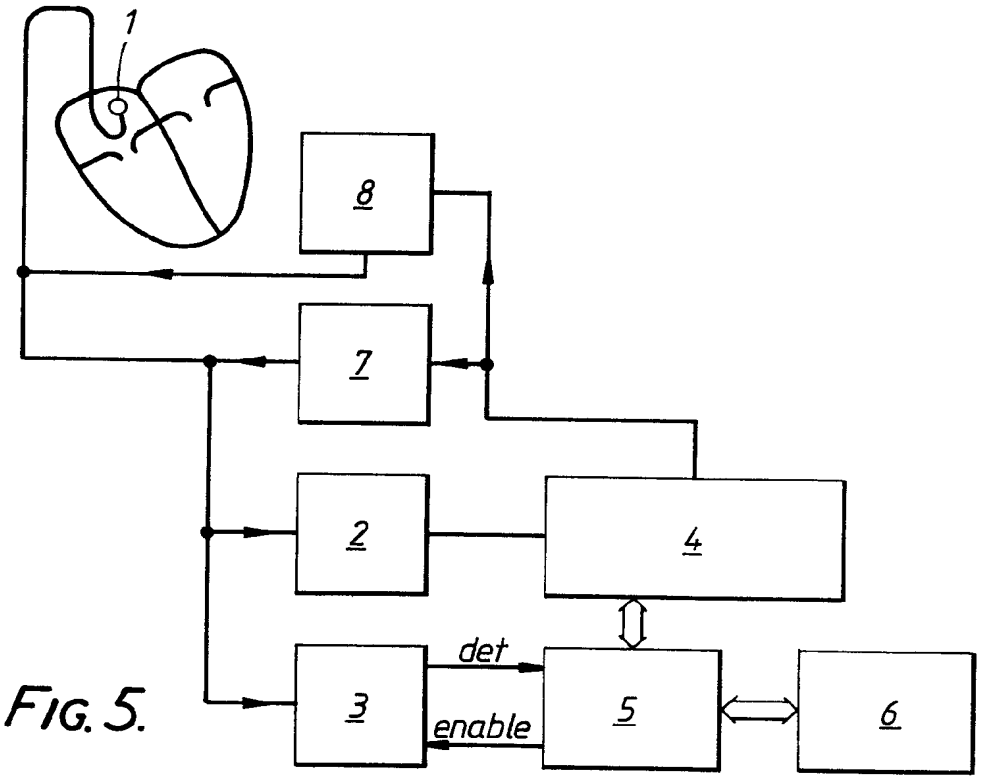

FIG. 5.

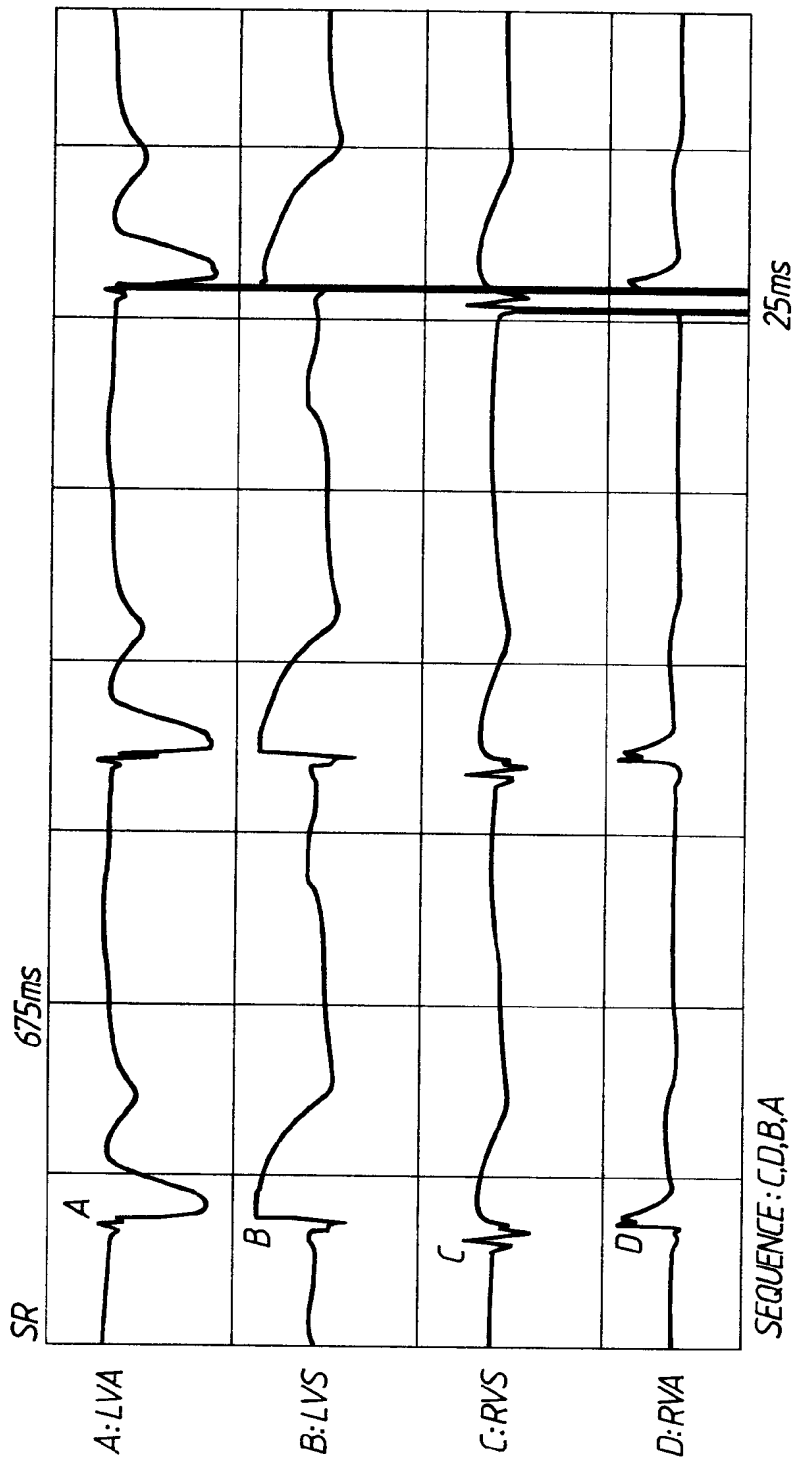

FIG. 2.

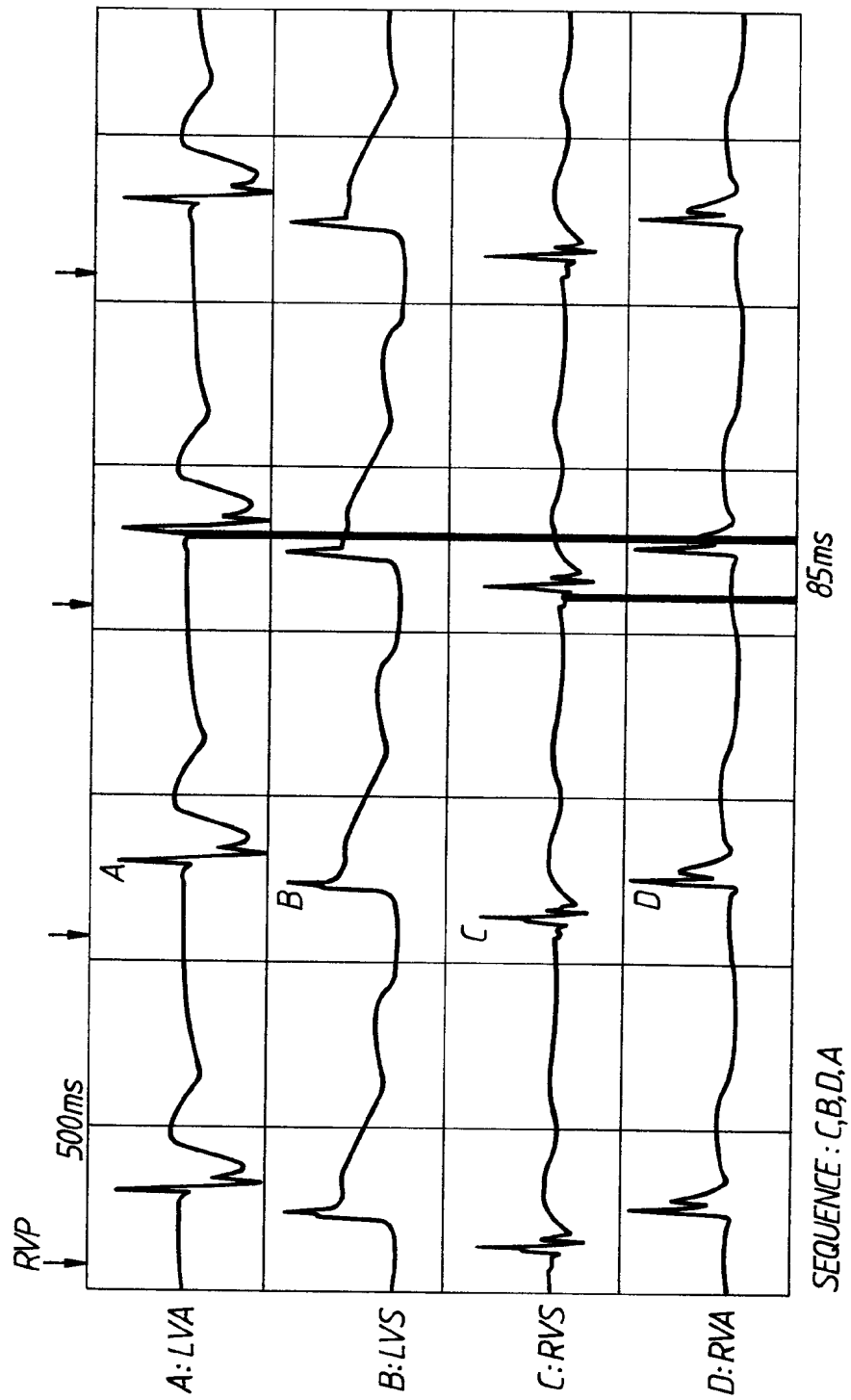

FIG. 3A

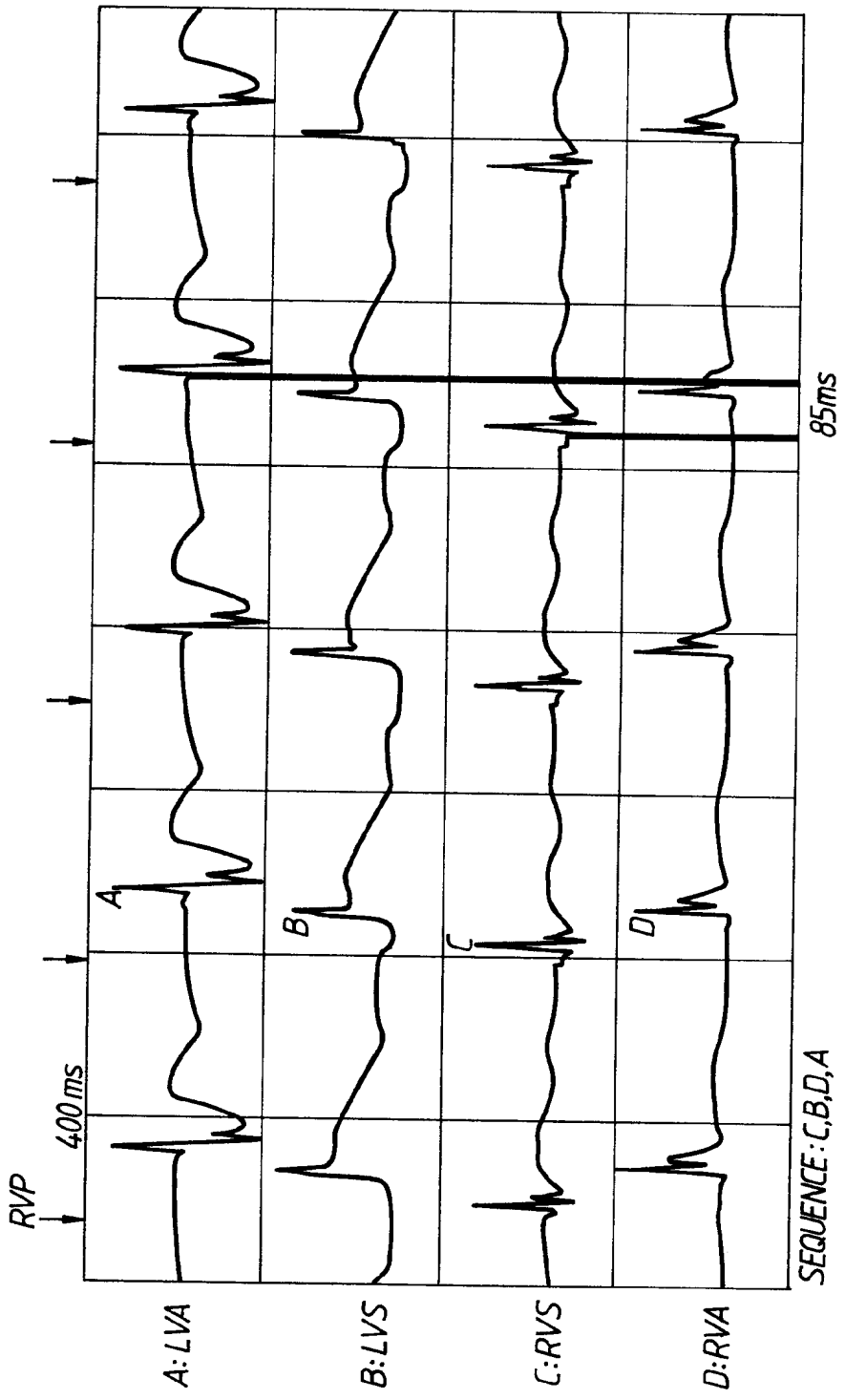

FIG. 3B.

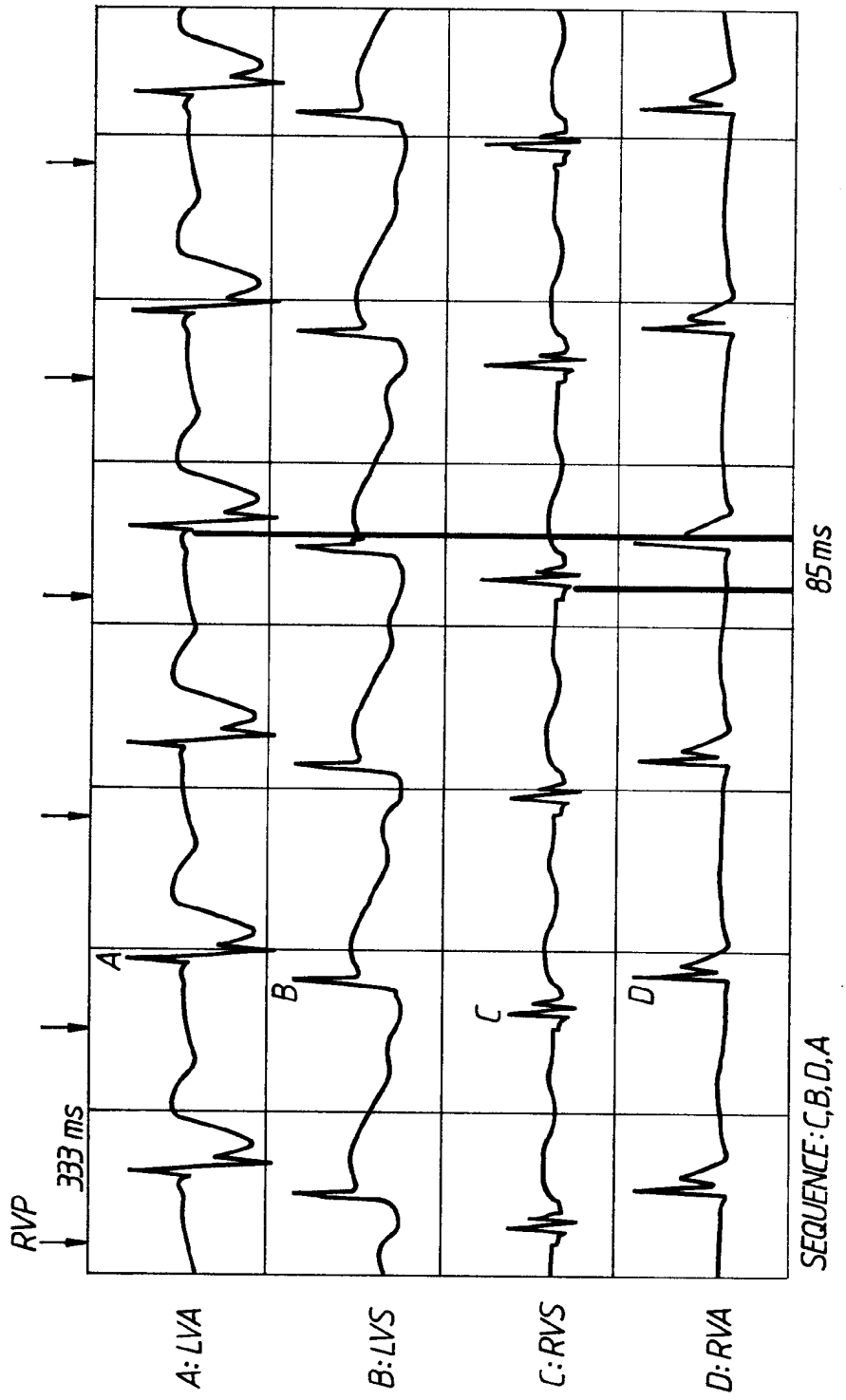

FIG. 3C.

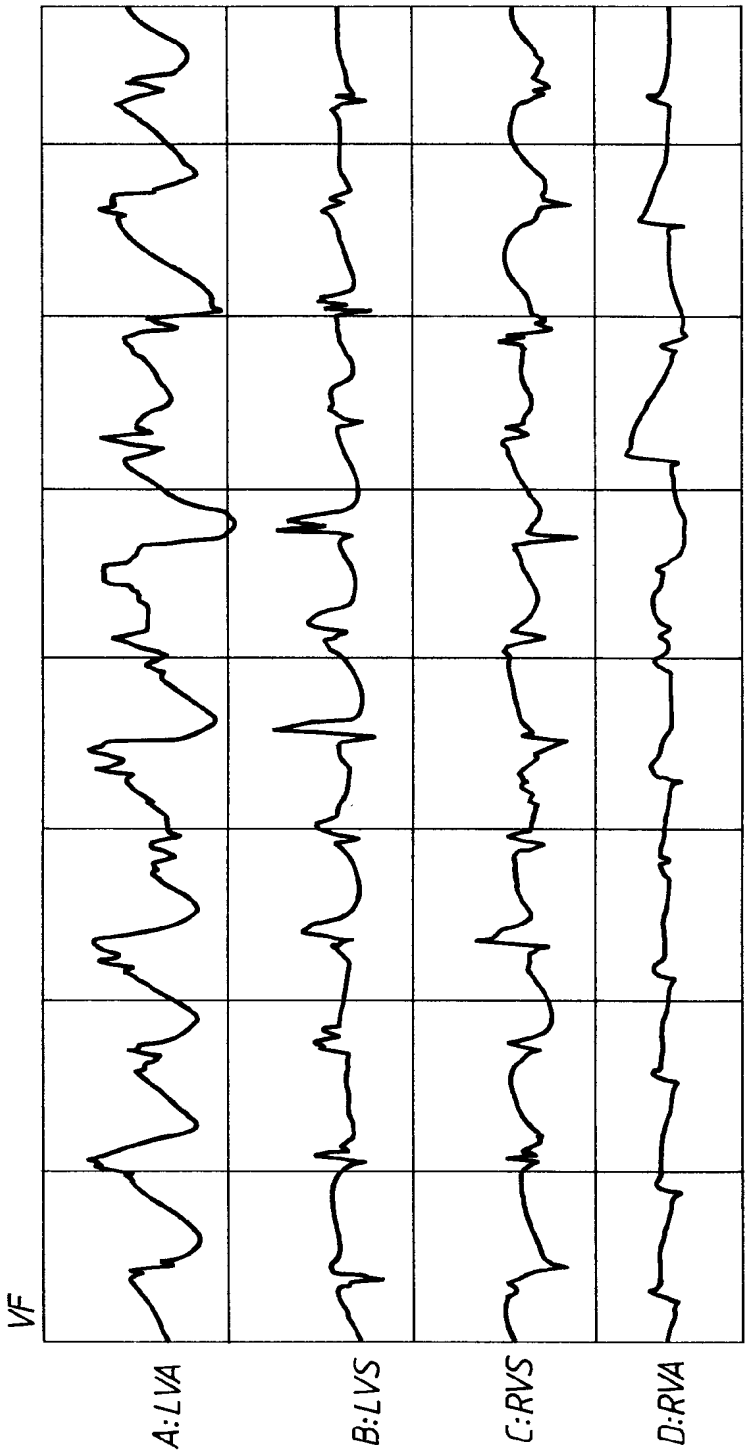

FIG.4.

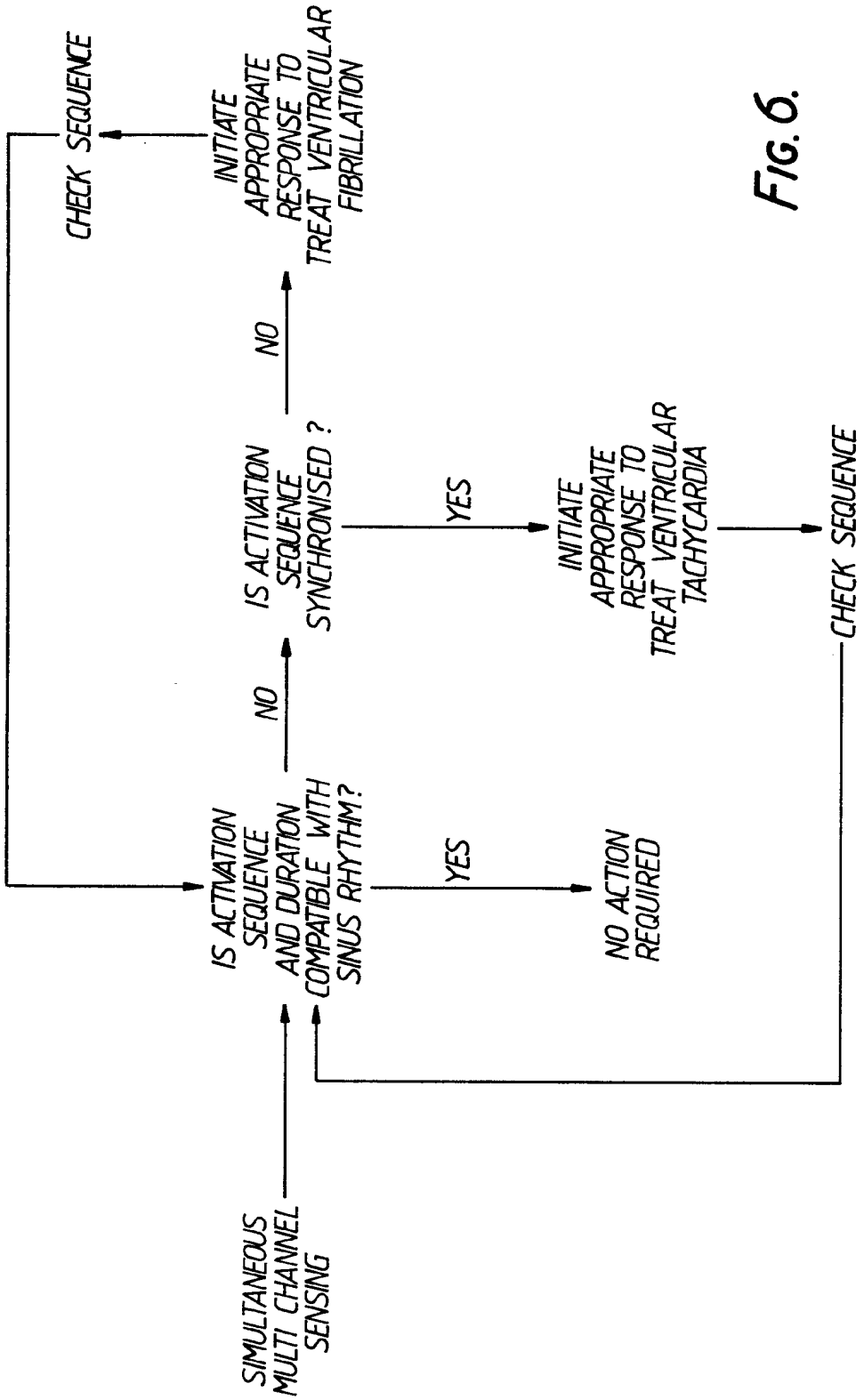
SIMULTANEOUS MULTI CHANNEL SENSING
IS ACTIVATION SEQUENCE AND DURATION COMPATIBLE WITH SINUS RHYTHM?
NO
IS ACTIVATION SEQUENCE SYNCHRONISED ?
NO
INITIATE APPROPRIATE RESPONSE TO TREAT VENTRICULAR FIBRILLATION
CHECK SEQUENCE
YES
INITIATE APPROPRIATE RESPONSE TO TREAT VENTRICULAR TACHYCARDIA
CHECK SEQUENCE
YES
NO ACTION REQUIRED

FIG. 6.

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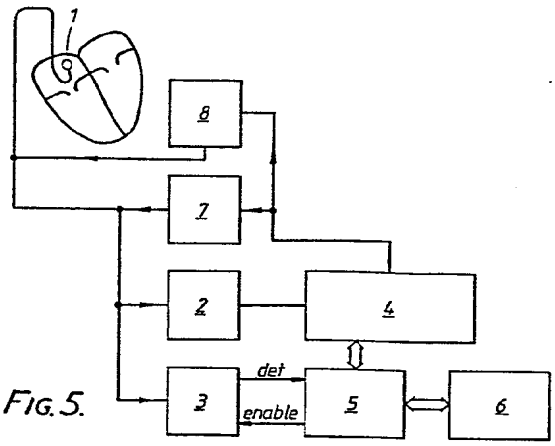

FIG. 5.

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EUROPEAN SEARCH REPORT

Application number 0220916

EP 86 30 8150

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
X	WO-A-8 200 415 (MIROWSKI) * Abstract; page 4, line 1 - page 6, line 21 *	1-3	A 61 N 1/36 A 61 N 1/38
Y	EP-A-0 001 708 (MEDTRONIC) * Page 4, line 12 - page 5, line 18; page 10, line 1 - page 11, line 8 *	1-8	
A	US-A-4 432 375 (ANGEL) * Abstract; claims 1-3 *	1-3	
Y	IEEE TRANSACTIONS ON BIOMEDICAL ENGINEERING, vol. BME-29, no. 5, May 1982, pages 359-361, IEEE, New York, US; A.R.S. BUKHARI et al.: "Cardiac arrival time analyzer" * Whole document *	1-8	
A	PROCEEDINGS OF THE IEEE, vol. 67, no. 9, September 1979, pages 1322-1337, IEEE, New York, US; L.J. THOMAS Jr. et al.: "Automated cardiac dysrhythmia analysis" * Abstract; figures 1-2 *		

TECHNICAL FIELDS SEARCHED (Int. Cl.4)

A 61 B
A 61 N

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	29-09-1987	DELEU A.J.H.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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